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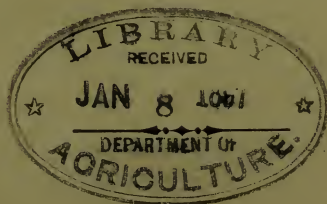
U.S. DEPARTMENT OF AGRICULTURE.
DIVISION OF ENTOMOLOGY.
BULLETIN No. 6.
(SECOND EDITION.)

THE IMPORTED
ELM LEAF-BEETLE.

ITS HABITS AND NATURAL HISTORY,

AND

MEANS OF COUNTERACTING ITS INJURIES.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF SUBMITTAL.

DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., October 19, 1891.

SIR: I have the honor to submit for publication a second edition of Bulletin No. 6 of this Division, on the Imported Elm Leaf-beetle, as there is constant demand from correspondents for information on the subject. The original edition was published in 1885 and has long since been exhausted. The substance of the bulletin was subsequently reprinted in Bulletin No. 10 of this Division, which is, however, more comprehensive than is necessary for specific distribution to persons interested in this insect alone. The present edition is in the main a reprint, but a few additional facts are added in an appendix.

Respectfully,

C. V. RILEY,
Entomologist.

Hon. J. M. RUSK,
Secretary of Agriculture.

THE IMPORTED ELM LEAF-BEETLE.

(*Galeruca xanthomelæna** Schrank.)

Order COLEOPTERA; family CHRYSOMELIDÆ.

The depredations of this pest have now become widely extended throughout the Northeastern States, rendering unsightly and almost worthless those most valuable shade trees of our cities—the elms. As its injuries are so far unknown in the Mississippi Valley, the blighted appearance of the elms on the Department grounds in midsummer, and especially of the European varieties, at once attracted our attention when we first came to Washington, and a series of experiments was begun with a view of checking the ravages of the insect. The excellent opportunities thus offered for experiment and study have since been improved, and, with some prefatory passages in relation to the history and habits of the beetle, we will give the practical results reached.

AN IMPORTATION FROM EUROPE.

This beetle has done great mischief in the Old World, especially in Germany and France, and it is very important that the public know the best method of coping with it here. According to Glover, it was imported as early as 1837. Its distribution was formerly confined to limited areas near the coast, and its earlier attacks were notably about Baltimore and New Jersey.

HABITS AND NATURAL HISTORY.

The general characteristics of this insect have been pretty well studied abroad. Mr. E. Heeger† has given an excellent account of its life history, with a detailed description of the larva, and figures illustrating larva and pupa and anatomical details. More recently M. Maurice Girard‡ has given a rather poor wood-cut illustration of the insect and its work, with the leading facts concerning its nomenclature and nat-

* This is the *Galeruca cratægi* Forst., and *G. californiensis* Fabr. In Crotch's Check List it appears as *Galerucella xanthomelæna*.

† Seventeenth contribution to the natural history of insects. Sitzungsberichte der. kais. Ac. Wiss., Wien, 1858, vol. 29, p. 100-120, 6 pl.

‡ Note sur la Galérucque de l'orme. Bull. d'Insectologie Agricole, 1878, III, pp. 113-116.

ural history as observed in Europe. Biological notes on the insect have also been given by Leinweber* and Kollar.†

In our country the life history of the insect and its injury have been referred to by Harris, Fitch, Morris, Walsh, and ourselves, while the agricultural papers contain numerous references to the injury inflicted by the insect. The perfect beetle has often been described in systematic works on Coleoptera.

For these reasons we deem it unnecessary to enter here into a detailed description of the beetle and its earlier stages, but content ourselves with pointing out the more obvious characters, alluding to such facts of the life history as are necessary to a full understanding of the nature of the remedies to be applied for this pest.

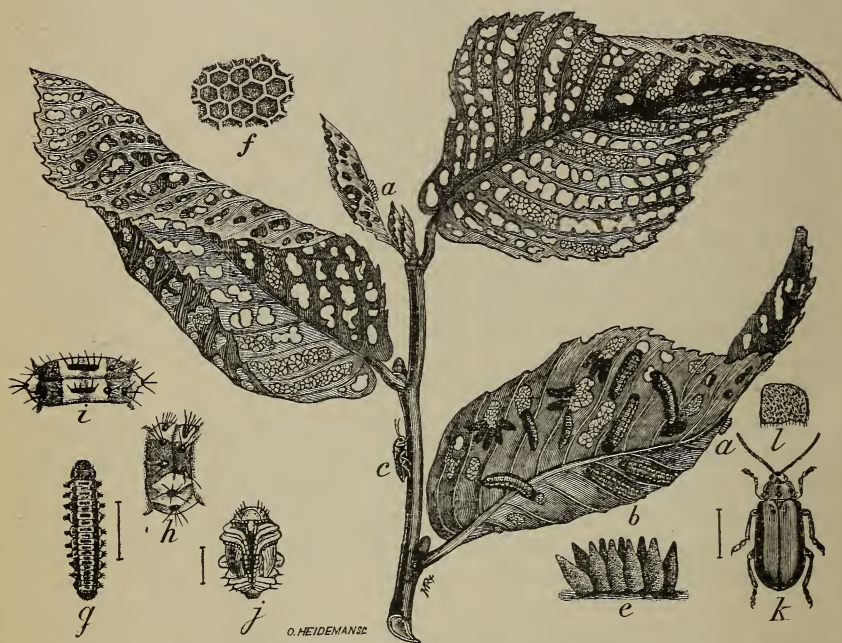


FIG. 1.—*Galeruca xanthomelæna*: a, eggs; b, larvæ; c, adults; e, eggs (enlarged); f, sculpture of egg; g, larva (enlarged); h, side view of greatly enlarged segment of larva; i, dorsal view of same; j, pupa (enlarged); l, portion of elytron of beetle (greatly enlarged).—After Riley.

The eggs are deposited in an upright position upon the under side of the leaves (Fig. 1 a), always in a group, consisting generally of two, rarely three, more or less irregular rows. The individual eggs are close together in each group (Fig. 1 e, magnified), and so firmly fastened to the leaf that they can only be detached with great care without breaking the thin and brittle shell. The number of eggs in each group varies from four or five to twenty or more. Very rarely only three eggs are seen in one

* Verhandlungen zool. bot. Ges., Wien, 1856, VI; Sitzb., pp. 74-75.

† *Op. cit.*, 1858, VIII; Abh., pp. 29-30.

group, but we never found less than that number. The egg itself is oblong oval, obtusely, but not abruptly, pointed at tip, of straw-yellow color, its surface being opaque and beautifully and evenly reticulated, each mesh forming a regular hexagon, as shown, highly magnified, in Fig. 1 *f*. The form of the eggs is not quite constant, some of them, especially those in the middle of a large group, being much narrower than others. The duration of the egg state is about one week.

The general shape of the larva is very elongate, almost cylindrical, and distinctly tapering posteriorly in the early stages, but less convex and of nearly equal width when mature. The general color of the young larva is yellowish-black, with the black markings comparatively larger and more conspicuous, and with the hairs arising from these markings much longer and stiffer than in the full-grown larva. With each consecutive molt the yellow color becomes more marked, the black markings of less extent and of less intense color, and the hairs much shorter, sparser, and lighter in color. A nearly full-grown larva is represented in Fig. 1 *g*, and in this the yellow color occupies a wide dorsal stripe and a lateral stripe each side. The head (excepting the mouth parts and anterior margin of the front), the legs (excepting a ring around the trochanters), and the posterior portion of the anal segment are always black. The first thoracic segment has two large black spots on the disk, of varying extent, and often confluent. The following segments (excepting the anal segment) are dorsally divided by a shallow transverse impression into two halves, and the black markings on these halves are arranged as follows: Two transverse dorsal markings, usually confluent, as shown in our figure; two round and sublateral spots; the tips of the lateral tubercles are also black. The abdominal joints of the ventral surface have each a transverse medial mark, and two round sublateral spots of black color. Stigmata visible as small umbilicate spots between outer sublateral series of dorsal markings and lateral tubercles. The yellow parts of the upper side are opaque, but those of the underside shining. The black markings are polished, piliferous, and raised above the remaining portions of the body.

The larvæ are destructive to the foliage from the month of May until August. They have about two weeks of active life between the egg and pupa states. During this time they prey upon the leaves, which become skeletonized, leaving the venation and commonly a certain portion of the flesh of the leaf, which becomes rust brown. They undergo four molts, respectively observed at Washington on July 15 (at hatching), 20, 23, and 29 (pupation). When full grown they descend to the ground and change to pupæ under whatever shelter is near to the base of the tree.

The pupa is of brighter color than the larva, oval in shape, and strongly convex dorsally. It is sparsely covered with moderately long but very conspicuous black bristles, irregularly arranged on head and thorax, but in a transverse row on each following segment. The pupa state lasts from about six to ten days.

The perfect beetle (Fig. 1 *c*, natural size; *k*, magnified) resembles somewhat in appearance the well-known striped Cucumber-beetle (*Diabrotica vittata*), but is at once distinguished by the elytra not being striate punctate, but simply rugose, the sculpture under high magnifying being represented in Fig. 1 *l*. The color of the upper side is pale yellow or yellowish-brown, with the following parts black: On the head a frontal (often wanting) and a vertical spot; three spots on the thorax; on the elytra a narrow stripe along the suture, a short, often indistinct scutellar stria each side,

and a wider humeral stripe not reaching the tip. Under side black, pro- and meso-sternum and legs yellow, femora with a black apical spot. Upper and under side covered with very fine, short, silky hairs. In newly-hatched individuals the black markings have a greenish tint; the humeral stripe varies in extent.

The beetle assists the larva in its destructive work, but, as usual in such cases, the damage done by the perfect insect is small when compared with that done by the larva. There are two or more annual generations of the insect, judging from the facts that have been collected, the number varying doubtless with the latitude. In the month of September the beetles prepare for hibernation, seeking shelter in hollow trees, in the ground, under old leaves, etc., and remain dormant until the following spring.

REMEDIES.

M. Girard says:

There is no other means of destruction than to jar the branches over cloths to collect the larvæ and adults which fall. It is also possible when they are on the ground to distribute on them boiling water or steam, or even quicklime or solution of sulpho-carbonate of potassium.

In our own country much more has been accomplished toward practically combating this insect.

In the U. S. Agricultural Report of 1867, Glover suggested the use of oil and tar gutters and other barriers surrounding the base or the body of the tree, devices similar to those used against the Canker Worm and Codling Moth. He then and afterward (1870) recommended "to place around each tree small, tight, square boxes or frames, a foot or 18 inches in height, sunk in the earth; the ground within the inclosure to be covered with cement, and the top edge of each frame to be covered with broad, projecting pieces of tin like the eaves of a house or the letter T, or painted with some adhesive or repellant substance, as tar, etc. The larvæ descending the tree, being unable to climb over the inclosure, would change into helpless pupæ within the box, where they could daily be destroyed by thousands. Those hiding within the crevices of the bark of the trunk could easily be syringed from their hiding places." (U. S. Agricultural Report, 1870, pp. 73, 74.) These boxes were carefully tested at this Department, and they worked as described. While coal tar and other adhesives were recommended, we have found scalding-hot water most convenient for destroying the insects that accumulate in the inclosure or upon the ground elsewhere. Where branches are low and droop near the ground some of the larvæ descend the wrong way and fall off, but shade trees should not be allowed to grow in this low, drooping manner, and under all ordinary circumstances, where the branches are not severely jarred to encourage the insects to drop, the larvæ will descend by the trunk and become captured in the devices here noticed.

Mr. Glover regarded the pupa state as the most favorable in which to kill the insect, as it can then be easily crushed or scalded. Concerning the tobacco treatment, he adds that "syringing the trees with strong

tobacco water has been tried with some good effect, but the larvæ not touched by the fluid are merely knocked down by the concussion, and, if nearly ready to change into pupæ, effect their transformation where they fall."

In this connection we can not do better than quote what we published in 1880* in reply to certain statements by Dr. J. L. LeConte, as follows:

Anent *Galeruca xanthomelæna*, which is becoming more destructive each successive year to the shade elms in our northern towns, a correspondent mentions the following facts:

1. The trees are not all attacked at the same time, but the insect seems to break out from a center, gradually destroying the more remote trees, so that isolated trees remain comparatively free.

2. After applying a band (saturated with fish oil, petroleum, etc.) to some trees which were about half denuded, found hundreds of the worms stopped both in ascending and descending the trees.

He also propounded the following query:

3. Do the beetles hibernate in the ground, so that they can be poisoned, or are they perpetuated only by the eggs on the trees?

Allow me to add the following subjects for investigation as necessary to the devising of proper remedies against this foreign invader:

4. How soon do the insects appear in the spring; how rapidly do they propagate; and what time is passed in each stage of development?

5. Are the larvæ and beetles eaten by insectivorous birds; or are they protected by offensive secretions, as is the case with *Doryphora 10-lineata*, *Orygia leucostigma*, and several other noxious insects?

6. What proportion of the brood hibernates, and in what stage, pupa or perfect insect, and where?

If the materials for furnishing answers to these questions are not yet within your reach, will you kindly direct the attention of some of your trusty observers to the subject, so that persons interested in the preservation of the shade trees which are so justly esteemed may be properly instructed as to the measures to be adopted during the next summer.

Very truly yours,

J. L. LECONTE,
Philadelphia, Pa.

The above inquiries were received from our esteemed correspondent some timesince, and we employ them as a ready means of giving our experience with the beetle.

For the benefit of the general reader it may be remarked that the natural history of this Elm Leaf-beetle is quite similar to that of the well-known Colorado Potato-beetle and of the Grape-vine Flea-beetle. The only deviation in the Elm Leaf-beetle is in the mode of pupation, which rarely takes place in the ground, unless this be very friable, but at the base of the tree or under any shelter that may present itself near the trees, such as old leaves, grass, etc.

(1) The phenomenon here described is doubtless due to the gradual increase in spring from one or more females.

(3 and 6) Like most, if not all, *Chrysomelidæ*, the Elm Leaf-beetle hibernates in the perfect state. As places suitable for hibernation abound, any attempt to successfully fight this pest in winter time, with a view of preventing its ravages the subsequent season, will prove fruitless. A large proportion of the hibernating beetles doubtless perish, since the insect is comparatively scarce in the earlier part of the season.

(4 and 5) The beetles fly as soon as spring opens, and we have observed the first larvæ early in May, in Washington, D. C., or sometime after the elm leaves are fully developed. The ravages of the insect begin to be apparent with the second generation of larvæ, which appear in June.

In 1878 we made many notes and experiments on the species, and the development of the third and most injurious generation occupied about one month. The numerous pupæ which in the latter part of August were to be found under the trees were mostly destroyed that year, partly by continuous wet weather prevailing at the time, partly by the many enemies of the insect. Among these there are *Platynus punctiformis* and *Quedius molochinus*, which feed on the full-grown larvæ when these retire for pupation, and also on the pupæ. The larva of a *Chrysopa* (probably *C. rufilabris*) feeds upon the eggs of the *Galeruca*, *Reduvius novenarius* sucks both beetles and larvæ on the leaves, while *Mantis carolina* preys upon the beetle. Of the numerous other insects found among the pupæ under the trees, *e. g.*, *Tachyporus jocosus*, sundry spiders, myriapods, etc., several are doubtless enemies of the *Galeruca*, though we have as yet no proof of the fact. Many birds were observed on the trees infested by the beetles, but the English Sparrow, which was the most numerous, did not feed on the insect in any stage of growth.

The only method of warfare against this pest recommended by European writers is to jar the larvæ down upon sheets, and then in one way or another to destroy them. This may answer for young trees, but is then tedious and but partial. We found that the quickest and most satisfactory way of destroying the insect and protecting the trees was by the use of Paris green and water in the manner frequently recommended in these columns, and London purple will evidently prove just as effectual and cheaper. The syringing can not be done from the ground except on very young trees, though a good fountain pump will throw a spray nearly 30 feet high. Larger trees will have to be ascended by means of a ladder and the liquid sprinkled or atomized through one of the portable atomizers, like Peck's, which is fastened to the body, and contains 3 gallons of the liquid.

The mode of pupation of the insect under the tree, on the surface of the ground, beneath whatever shelter it can find, or in the crevices between the earth and the trunk, enables us to kill vast numbers of the pupæ and transforming larvæ by pouring hot water over them. We found that even Paris-green water poured over them also killed. If the trees stand on the sidewalk of the streets the larvæ will go for pupation in the cracks between the bricks or at the base of the tree, where they can also be killed in the same way. This mode of destruction is, take it all in all, the next most satisfactory one we know of, though it must be frequently repeated.

(2) We have largely experimented with a view of intercepting and destroying the larvæ in their descent from the tree. Troughs, such as are used for Canker-worms, tarred paper, felt bands saturated with oil, are all good and the means of destroying large numbers. Care must be taken, however, that the oil does not come in contact with the trees, as it will soon kill them, and when felt bandages are used there should be a strip of tin or zinc beneath them. The trouble with all these intercepting devices, however, is that many larvæ let themselves down direct from the tree and thus escape destruction.

In conclusion we would remark that it is highly probable that Pyrethrum powder stirred up in water might be successfully substituted for arsenical poisons, but experiments in this direction have not yet been made. From experiments we have made with dry, unmixed powder, we found that it affects very quickly the larva, pupa, and the perfect insect, but in order to be applied on a large scale and on large trees the powder must of course be mixed in water. There is, however, no danger in the judicious use of the arsenical liquids upon shade trees.

MORE RECENT EXPERIENCE AT THE DEPARTMENT.

The more recent experience in the destruction of this *Galeruca*, on the Department grounds, may now be summed up, the experiments having been intrusted to Dr. Barnard.

Past History of the Elms in question.—According to Mr. William Saunders, of this Department, these trees have been annually attacked by the European Elm Leaf-beetle since they were planted ten years ago, and about one year in three the injury has been severe, resulting in their defoliation, while in other years, as in 1879 and 1880, there appeared comparatively none. In some seasons a second or autumnal set of leaves appeared after the trees had been stripped, and in certain of these instances the second crop of leaves became eaten; but in all cases he thinks the lives of the trees have not seemed to be endangered and they soon repaired the damage done. His belief is also that the pest did not become gradually worse and worse through the series of years during which it has been observed by him; still he regards the attack of 1882 as worse than any known to him before on these trees or others, and he has noticed the effects of this insect since 1850, first in its earliest ravages about Baltimore, and later elsewhere.

Condition and Characteristics of the Grove in 1882 and 1883.—However it may be for the past history or future desirability of certain trees in the grove, in 1882 many exhibited various grades of feebleness, and some had dying branches. Indeed, a few of them had a very unhealthy aspect the previous year also. Of course it can be claimed that their unhealthy condition is due to other causes than the insects; and it should be remembered that most are foreign species each often represented in two or more of its varieties. Here all grow on level ground, whereas in a state of nature some belong to mountainous localities, others to the damp climate of England, etc. Therefore, many of them are growing under abnormal conditions. They exhibit much variety in the relative abundance, size, form, and texture of the leaves. There is also great diversity in the density and form of branching.

Extent of Injury in 1882 and 1883.—All the varieties and species of elms in this grove, without exception, were preyed upon by the pest in 1882 and 1883. The insect, however, showed decided preferences for certain individual trees, varieties, or species, stripping some completely before doing more than very slight harm to the leaves of others, the former becoming completely eaten in midsummer, the latter not until toward the close of the season, or remaining only slightly damaged until then. In 1882 the leaves were eaten faster than they could be developed, and the insect continued abundant enough to prevent a second crop of foliage until in November, when it became too cold for the leaves and active insects to exist.

On these grounds the southeast side of each tree has suffered more than the northwest half. This peculiarity has been very strongly pronounced this year, 1883, on all the trees affected, and upon some examples far more markedly than upon others. This one-sidedness is especially apparent in the trees which were the most severely eaten. Some trees show the southeast side completely devoured but the northwest side only half consumed and comparatively green. Such are average cases.

The inferences have been that the shade, dampness, and coolness of the tree on the northwest side during the morning is too unhealthy for the favorable development of the larvæ or of the eggs deposited there; but whether this be true or not, the insect probably prefers to deposit chiefly in the middle of the forenoon, and on that part of the tree which is then warmest. This would give a greater number of the eggs at the outset on the southeast side, as observation seems to confirm, and since the young larvæ do not migrate to any noteworthy extent, the one-sidedness described would result whether the northwest side were unhealthy or not. The former explanation is most probably the correct one, as we have noticed that the insect is less injurious during very wet summers.

Preferences of the Elm Beetles for certain Varieties and Species of Elms.—The American slippery elm does not occur in this grove, but only one native species, the common American elm, *Ulmus americana*. This is practically free from the ravages of the beetle, on which account it may be preferred to the European species. It is tall, and has gracefully arched branches, making it as ornamental as any European kind, yet as a shade tree it does not equal the *U. montana* of the Old World. The latter has a broader, denser crown, but the attack on it is considerable, enough to leave the choice in favor of the American species.

U. montana seems the best European species grown here for shade, since the other foreign elms here cultivated are not dense enough. This applies to *U. campestris*, *U. suberosa*, *U. effusa*, and *U. parvifolia* (*siberica*). The last named is not attacked as much as the American. The young larvæ can not develop on it, but die quite soon, without growing, and they gnaw the leaves very little. The other foreign species mentioned are seriously eaten; the severest attack being upon the *U. campestris*, the favorite food of this insect.

As early as June 25, in 1883, this species was completely eaten and brown in our grove, at which date the *U. montana* examples retained more than half their verdure—in some individuals nearly all—and the common American elm was perfectly green. The *U. campestris* is one of the poorest elms for shade, and its total abolishment throughout the entire country would probably lessen the assault on *U. montana* to a comparatively unobjectionable extent. This measure should be instituted against the pest, and for the sake of the other species of elms.

Effects of arsenical Poisons on Insect and Plant.—Species of elms are somewhat differently affected by the poison. When treated alike there is always manifest some difference in the susceptibility of different elms to the corrosive effects of the poison. Even individuals of the same species or variety are differently impaired. As a rule, those which suit the insect best are injured most by the poison, and those which resist the insect most withstand the poison best. The latter have coarser foliage, with darker green color and more vigorous general growth; the former have more delicate foliage, lighter in color and weight, apparently less succulent.

Certain elms of the species *U. campestris* and other species which were overpoisoned, and shed most of their leaves in consequence in the last of June, 1883, sent out a profuse new growth of leaves and twigs. The foliage fell gradually for three weeks, and this was somewhat promoted by the succeeding rains.

The larvæ move from place to place so seldom that if the leaves are imperfectly poisoned from the mixture being weakly diluted, or from its application only in large scattered drops, which are much avoided by the larvæ, they are not killed off thoroughly for several days, and in all cases it requires considerable time to attain the full effect of the poison. This result appears on the plant and on the insect. After each rain the poison takes a new effect upon the plant and the pest, which indicates that the poison is absorbed more, or is more active when wet, and that it acts by dehydrating thereafter. Where the tree is too strongly poisoned, each rain causes a new lot of leaves to become discolored by the poison or to fall. On some of the trees the discoloration appears in brown, dead blotches on the foliage, chiefly about the gnawed places and margins, while in other instances many of the leaves turn yellow, and others fall without change of color. The latter may not all drop from the effects of poison, but the coloration referred to is without doubt generally from the caustic action. The poison not only produces the local effects from contact action on the parts touched by it, but following this there appears a more general effect, manifest in that all the foliage appears to lose, to some extent, its freshness and vitality. This secondary influence is probably from poisoning of the sap in a moderate degree. When this is once observable, no leaf-eater thrives upon the foliage. Slight overpoisoning seems to have a tonic or invigorating effect on the tree.

Preventive Effects of the Poison.—In this grove the elms that were poisoned in 1882 were attacked in the spring of 1883 less severely than were those which were not poisoned the previous year. This would seem to imply that the insects deposit mostly on the trees nearest to where they develop, and are only partially migratory before ovipositing. The attack afterward became increased, probably by immigration and the new generation, so that later in the season the trees were mostly infested to the usual extent.

In the region of Washington a *preventive application of poison should be made* before the last of May or first of June, when the eggs are being deposited and before they hatch. This will prevent the worms from ever getting a start. By the preventive method the tree escapes two kinds of injury: first, that directly from the eating by the insect; second, that which follows indirectly from the deleterious effects of the poison on the plant, for its caustic effect is much greater where the leaves have been so gnawed that the poison comes in contact with the sap.

Treatment with London Purple.—Already early in June the insect appears plentiful. On June 7, 1882, it was at work on all the trees, and

its clusters of eggs were numerous beneath the leaves. Some of the trees had half of the leaves considerably gnawed and perforated by larvæ of all sizes, and by the adults. At this date fifteen trees, constituting the south part of the grove, were treated.

Preparation of the Poison.—London purple (one-half pound), flour (3 quarts), and water (barrel, 40 gallons) were mixed, as follows: A large galvanized iron funnel of 13 quarts capacity, and having a cross-septum of fine wire gauze such as is used for sieves, also having vertical sides and a rim to keep it from rocking on the barrel, was used. About 3 quarts of cheap flour were placed in the funnel and washed through the wire gauze by water poured in. The flour in passing through is finely divided, and will diffuse in the water without appearing in lumps. The flour is a suitable medium to make the poison adhesive. The London purple is then placed upon the gauze and washed in by the remainder of the water, until the barrel is filled. In other tests the flower was mixed dry with the poison powder, and both were afterward washed through together with good results. It is thought that by mixing in this way less flour will suffice. Three-eighths of a pound of London purple to one barrel of water may be taken as a suitable percentage. Three-eighths of an ounce may be used as an equivalent in one bucketful of water. The amount of this poison was reduced to one-fourth of a pound to the barrel with good effect, but this seems to be the minimum quantity, and to be of value it must be applied in favorable weather and with unusual thoroughness. With one-half or three-fourths of a pound to the barrel about the maximum strength allowable is attained, and this should be applied only as an extremely fine mist, without drenching the foliage.

Effects of the Mixture.—The flour seems to keep the poison from taking effect on the leaf, preventing to some extent the corrosive injury which otherwise obtains when the poison is coarsely sprinkled or too strong. It also renders the poison more permanent. On the leaves, especially on the under surfaces, the London purple and flour can be seen for several weeks after it has been applied, and the insect is not only destroyed, but is prevented from reappearing, at least for a long period. By poisoning again, a few weeks later, the insect is deterred with greater certainty for the entire season. By being careful to administer the poison before the insect has worked, and, above all, to diffuse the spray finely but not in large drops, no harm worth mentioning will accrue to the plant from the proportion of poison recommended. The new growth that developed after the first poisoning was protected by one-fourth of a pound to the barrel in 1882. From midsummer until autumn the unpoisoned half of the grove remained denuded of foliage, while the poisoned half retained its verdure. The little damage then appearing in the protected part was mostly done before the first treatment. Eggs were laid abundantly throughout the season. Many of these seemed unhealthy and failed to develop, probably because they were poisoned. Many hatched, but the young larvæ soon died. The

eggs were seldom deposited on the young leaves that were appearing after the poison was applied, but were attached to the developed leaves, and here the larvæ generally got the poison to prevent their attack upon the aftergrowth. Still the young leaves became perforated to some extent. The adults, which fly from tree to tree, appeared plentiful without much interruption throughout the season, and often several could be seen feeding on each tree. Possibly many of these may have become poisoned before depositing the eggs.

The efficiency of London purple being established, it will generally be preferred to other arsenicals, because of its cheapness, better diffusibility, visibility on the foliage, etc. As the effects of the poisons commonly do not appear decidedly for two or three days after their administration, the importance of the preventive method of poisoning in advance can not be too strongly urged. As the effect is slow in appearing, impatient parties will be apt to re-poison on the second or third day, and thus put on enough to hurt the plant when the effect does come. Much depends on dryness or wetness of the weather, but good effects may be expected by the third or fourth day.

London purple seems to injure the plant less than Paris green.

Treatment with Paris Green.—In 1883 the Paris green was first applied on the 29th of May, at which date the eggs were extremely abundant and hatching rapidly on the leaves. Paris green, flour, and water were mixed by the means previously employed with London purple and already described. The mixture was applied to the north part of the same grove of elms. Thus far experience shows that the Paris green is effective against the insect, but that this poison injures the plant more than does the London purple.

Three-fourths of a pound of Paris green to a barrel (36 or 40 gallons) of water, with 3 quarts of flour, may be regarded as a poison mixture of medium or average strength for treating elms against these beetles, and the indications thus far are that the amount of Paris green should not be increased above 1 pound or be diminished much below one-half a pound in this mixture. To a bucketful of water three-fourths of an ounce of Paris green may be used. The action of this poison is slow but severe, and varies much with the weather. Thus far the results of tests have been varied so much by the weather and different modes of preparation and application that they will be repeated. When used strong enough to cauterize the leaves the poisonous action upon the plant may be observed to continue for several weeks.

Mechanical Means of Applying the Poison.—When many trees were to be sprayed a cart or wagon was employed to haul the poison in a large barrel provided with a stirrer, force-pump, skid, etc. The following brief account of the skid, mixer, barrel, and pump may be reproduced here from our last Annual Report:

The skid is a simple frame to hold the horizontal barrel from rolling, and consists of two pieces (Pl. I, Fig. 3 *aa*) of wood, about the length of the barrel, and in section about 3 by 4 inches, joined parallel, apart from each other, by two cleats, *bb*. The

inner upper angles may be cut to match the curve of the barrel, as at *cc*. The barrel being placed upon this frame is next to be filled.

A good device for mixing the poison thoroughly with the water and for filling the barrel is shown in section in Pl. 1, Fig. 4. It consists of a large funnel that will hold a bucketful, and has cylindrical sides, *gg*, that rest conformant on the barrel. In this is a gauze or finely perforated diaphragm or septum, *d*, and a funnel base, *tt*, with its spout, *p*, inserted through the bung.

By reference to Pl. 1, Fig. 4, the barrel, *k*, will be seen in section, and some of its details, together with those of the pump and stirrer, may be noticed. The fulcrum, *f*, has a foot below, screwed to the barrel. Through its top is a pivot, *o*, on which tilts the pump-lever, *ii*, which is similarly hinged at *b* to the top of the piston-rod. The pump-cylinder, *q*, is also hung upon trunnions, *i*, projecting into eyes. In this illustration the eyes, *ee*, have each a neck fitting in a slot cut through the stave oppositely from the side of the bung-hole, and beneath the stave is a foot on the eye-piece. Its neck is so short that the eye is held down firmly against the top of the stave, while the foot is as tight against its under surface. The length of its eye-piece is a little less than the diameter of the bung-hole, into which it may be inserted to be driven laterally into the slot. The slot is longer than the eye-piece, so the latter may be driven away from the bung-hole for a distance greater than the length of the trunnion-pivot. Then the pump being inserted, until these pivots come opposite the eyes, the latter may be driven back as sockets over the pivots, which play in them when the pump is worked. To hold these eyes toward the pump and upon the trunnions a wedge, *v*, is driven in the slot beyond each eye-piece. Thus the pump is easily attached or removed, and its union with the barrel is strong and firm. Perchance it be desired that this pump hole be bunged, the side slots may be wedged to make the barrel tight.

The parts of the pump being hung as described, the hinge, *b*, forms a toggle-joint, and in its action causes the pump to oscillate on its trunnions, its basal end swinging wider than its top, as indicated by the dotted line from *x* to *y*. Upon the extremity of this swinging end is a loop, *h*, through which is passed a stirrer-bar, *m n*, made to sweep back and forth in the lower side of the barrel, thus to agitate and mix the substances considerably during the operation of the pump, every stroke of the handle causing one or two strokes of the stirrer.

The method of inserting and extricating the stirrer-bar is as follows: It is raised with the pump until the end, *n*, comes opposite the bung-hole, through which the bar may be pulled out by the cord, *w*, which is attached to the end, *n*, and also preferably to the bungs, *r* and *z*, as shown. Through the same hole the bar may be inserted. This stirring device is the simplest in construction and operation of any yet contrived, while working as it does with reference to the concavity of the barrel it is perfectly effective.

The pump is double acting and very powerful, giving strong pressure to disperse the liquid far and finely, for, with the eddy-chamber nozzle used, the greater the pressure the finer is the liquid atomized. A block or other catch may be fixed on the side of the barrel to fit against the skid and prevent the barrel from rocking therein, as might otherwise happen, when it is nearly empty, if much power is applied. About one pailful of poisoned water was sprayed upon each tree. When only two or three trees were to be treated, an aquapult or other bucket-pump was used to force the poison from a bucket carried by hand. The Paris-green mixture needs to be almost constantly stirred, as this poison precipitates quickly; but with London purple the agitation is only occasionally necessary.

Connected with either pump is a long, flexible pipe, with its distal part stiff, and serving as a long handle whereby to hold its terminal nozzle beneath the branches or very high up at a comfortable distance from the person managing it. Parts of one form of this extension pipe are shown in Figs. 1 and 2.

To the pump-spout is attached the long, 2-ply, flexible hose, *h h*, of $\frac{1}{4}$ -inch caliber. Its considerable length, 12 feet or more, allows the nozzle to be carried about the tree without moving the pump. Beyond its flexible part the hose, *h*, passes through a bamboo pole, *b*, from which the septa have been burned out by a hot iron rod. At the distal end of the pole the hose terminates in a nozzle, *n* or *m*. When the nozzle is in its natural position, *m*, the spray, *z*, is thrown straight ahead, and this suits well for spraying very high branches; but for spraying the under surfaces of the lower parts of the tree it is necessary that the nozzle discharge laterally from the pipe, and this is accomplished with a nozzle having a direct discharge by bending it to one side. The nozzle, *n*, and spray, *s*, are directed laterally, and the nozzle, *n*, is maintained in this position by a metallic hook or eye, *v*, having a crooked stem inserted at the side of the hose in the end of the pole. Where the side spray is permanently desired, the metallic stem is inserted inside the hose and connected with the base of the nozzle, or the tubular stem of the nozzle is given the desired crook. For small trees the simpler extension pipe shown in Fig. 2 is satisfactory. The metallic tube, *t*, several feet in length, is used as the stiff part, connected with the hose, *h*. One longer metallic pipe, having telescopic sections made tight by outside segments of rubber tubing, has also been employed, and is a very desirable extension-pipe. Where only low-end spraying is to be done, as upon small trees, etc., the eddy-chamber nozzle is set upon such a pipe, or upon its own stem, so as to discharge at right angles therefrom; but a diagonal position of the chamber, *n*, on its stem, *i*, throws the spray, *s*, at an intermediate angle between the right angle and a direct line, by which, without any readjustment, the spray, *s*, can be directed high or lower, beneath the foliage or above. For general use this kind of nozzle is the best. With ordinary force-pump pressure the discharge hole of the nozzle is about one-sixteenth of an inch in diameter for misty sprays with particles invisibly small. Rather than use the larger, coarser sprays, which were usually employed in these tests, it is better to use the finest spray. The spray falling upon the extension-pipe soon accumulates enough to flow down the pole and wet the hands. To prevent this a wrapping washer of leather or other flange may surround proximally from the spray, and the drip will drop off from its margin. Such an arrangement is indicated at *j* in Plate I, Fig. 1.

While one person operates the pump, another, standing in the vehicle or upon the ground, directs the spray by the stiff part of the pipe. Thus the operator can not only spray higher and lower with convenience, but he can to a great extent move the spray from place to place without

leaving his own position and without moving the vessel of poison with the pump.

The hose and bamboo combination was conceived of and used as the lightest long stiff tube practicable for these purposes, and it has answered admirably. A similar pole, with a metallic tube in its interior, with a nozzle not producing the very fine mist desired, and lacking the side discharge, etc., was afterward learned of as being used in California. (See U. S. Agricultural Department Report, 1881-'82, p. 208.)

By the apparatus used, when everything is prepared, a tree can be sprayed quickly, and a large grove is treated in a short time. It is equally adapted for forestry use in general, and likewise available for poisoning on fruit trees, when not in fruit, while the shorter style of extension pipe is convenient for underspraying all kinds of low plants.

APPENDIX.

One statement in the life history of the Imported Elm Leaf-beetle, as given in the preceding pages, may have to be corrected in the light of the observations of the past six years, and that is in reference to the number of annual generations. Like other leaf-beetles, this insect occupies an extended time in oviposition. The eggs appear to develop slowly in the ovaries, and a single female will deposit a number of the characteristic little yellow batches. This fact, taken in connection with the retardation of certain individuals of a generation, results in an inextricable confusion of broods. Adult beetles, pupæ, larvæ in all stages, and eggs, will be found upon trees at the same time in Washington during the months of June, July, August, and even later. From this fact it is almost impossible to estimate the number of annual generations without the most careful breeding-cage experiments. There is no evidence that the facts upon record are based upon such careful experiments. Glover, in the annual report of this Department for 1867, page 62, says: "After becoming pupæ, in a few days the skin of the back splits open and the perfect insect crawls forth, furnished with wings, by means of which it is enabled to fly to other trees and deposit its eggs, thus spreading the nuisance to every elm in the neighborhood; or it may ascend some tree and lay the eggs for a *second generation*, which destroys the second crop of leaves, frequently so enfeebling or exhausting the tree that it is unable to recover and eventually perishes." Again, in the Annual Report for 1870, page 73, he says: "The perfect beetles appear in a few days and immediately fly up into the tree to lay their eggs for a *second generation*, which frequently destroys every leaf on the tree."

The European records seem strangely silent upon this point. In the articles by Leinweber and Frauenfeld, referred to upon page 6, there is no indication of the number of generations, but it may be inferred that only one, namely, that of June and July, has been under observation. Heeger, however (*loc. cit.*, p. 114), says that "Under favorable circumstances there are three to four generations during the whole summer. Toward the end of August the insect ceases feeding and retires—partly as larvæ and partly as beetles—to winter rest under fallen leaves, in the cracks of bark, holes in the trunks of the trees, and in the ground itself." This observation was made near Vienna.

Our statement upon page 8 was a general one, based upon the ob-

served shortness of the larval life, and upon the fact that the earliest larvæ mature before the end of May, and upon the additional fact that we know that newly developed beetles are found early in June. Prof. John B. Smith, in a paper read before the Entomological Club of the American Association for the Advancement of Science, in August of this year, made the statement that there is but one annual generation in New Jersey. The adult beetles develop from the larvæ which have fed during the summer, entering winter quarters as early at the first week in August. This state of affairs may probably hold in more northern regions, but in Washington it is safe to say that there are two generations, because, as just stated, newly developed beetles (the progeny of those which hibernate) appear in early June. These lay eggs, and, in fact, egg-laying may continue until the end of September, and larvæ have actually been found by Mr. Pergande in October.

REMEDIES.

The spraying with arsenical poisons recommended in this bulletin has been generally adopted, and with universal success where proper precautions have been observed and where sufficient care has been taken. The most careful record of experiments that has been published was recorded by Prof. Smith in *Garden and Forest* for June 19, 1889. Prof. Smith's experience was interesting, not only because he treated some very large trees upon the Rutgers College campus, but from the fact that he has introduced a variation in the way of adding a small quantity of kerosene emulsion to the arsenical mixture for the purpose of making it spread over the leaves to wet them thoroughly. The dense velvety pubescence characteristic of the under side of certain elm leaves causes them to shed water readily, and this difficulty is overcome by the addition of the oil. The formula which he recommends is water, 100 gallons; London purple, 1 pound; standard kerosene emulsion, 1 gallon. This mixture he has found does not injure the foliage at New Brunswick. It is, however, stronger than is necessary, and the same amount of London purple and kerosene emulsion may be added to 150 or even 200 gallons of water with almost equal efficacy and with much greater safety. The difficulty of reaching the tops of tall trees was overcome by Prof. Smith in the following way: He used a hose 50 feet in length, to the end of which was attached a proper nozzle. The upper 10 feet were fastened to a bamboo pole of this length. With this he was able to throw a spray upon all branches 20 feet and over from the ground. Removing the spraying nozzle a solid jet could be thrown among the higher branches. This solid jet, he found, broke into quite a fine spray about 25 feet from the ground, and wetted the branches thoroughly to a height of 30 feet. A light ladder 20 feet in length gave him access to the center of the largest trees, whence the extreme tops could be reached. For the largest trees he used about 20 gallons of the mixture just mentioned. He was successful in destroying all the beetles and larvæ, and most of the eggs.

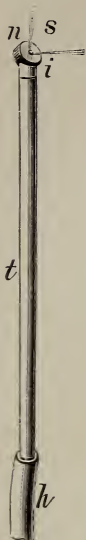


FIG. 2.

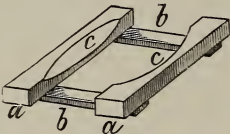


FIG. 3.

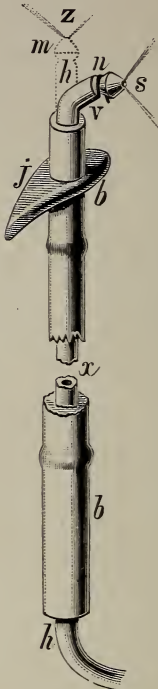


FIG. 1.

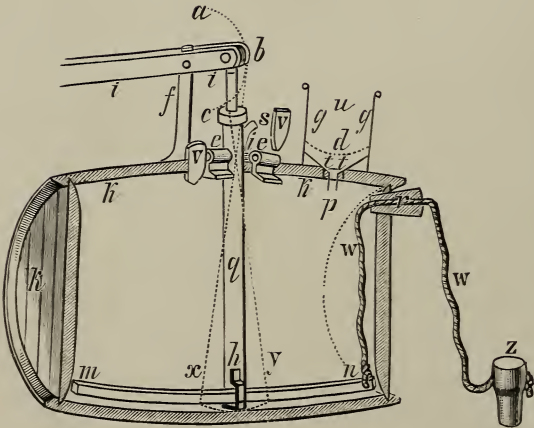


FIG. 4.

PLATE I.

DEVICES FOR UNDERSPRAYING TREES WITH INSECTICIDES.

[From Ann. Rept. U. S. Dept. Agr., 1883.]

- FIG. 1. *Parts of hose-pole device for spraying trees:* Bamboo pole, *b b*; drip-washer, *j*; hose, *h x*; side hook, *v*; eddy-chamber nozzle, *n m*; spray, *z s*.
- FIG. 2. *Metallic hand-pipe with diagonal nozzle:* Hose, *h*; metallic pipe, *t*; diagonal eddy-chamber nozzle, *n*; its removable face, *i*; spray, *s*.
- FIG. 3. *Barrel rest or skid:* Two coupling-cleats, *b b*; two side rests, *a a*; chamfered concave, *c c*.
- FIG. 4. *Stirrer-pump with barrel and mixer-funnel in section:* Funnel, *u*; its cylindrical sides, *g g*; funnel base, *t t*; spout, *p* (in bung-hole, *k*); gauze septum, *d*; barrel, *k k*; trunnions, *i*; trunnion-eyes, *e*; wedge, *v*; lever-fulcrum, *f*; pump-lever, *i i*; swing of the lever-head and piston-top, *a b c*; cylinder packing-cap, *c*; cylinder, *q*; its swing, *x y*; stirrer-loop or eye, *h*; stirrer-bar, *m n*; rope, *w w*; bungs, *r z*.



